

November 10, 1998

CRUISE RESULTS

Cruise 98-1 FV Vesteraalen Trawl Positioning Gear Trials 18-29 May 1998

The Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center (AFSC) conducted trawl positioning gear trials in Puget Sound in support of studies investigating potential impacts of bottom trawls on essential fish habitat. This study involved contract support from the U.S. Navy, Naval Undersea Warfare Center (NUWC) Division Keyport, Keyport, WA and Racal Pelagos, Inc., San Diego, CA.

AREA OF OPERATION

The gear trials were conducted at the NUWC fixed underwater tracking range in Dabob Bay (known as Dabob Range), Hood Canal, Puget Sound, WA. The Dabob Range is a fixed short baseline (SBL) hydrophone array operated by the NUWC to meet the U.S. Navy's needs for test and evaluation of weapon systems, ships, research and development, and fleet training. The range size is 23.3 km² (9 mi²) with water depth ranging from 36 to 183 m (120 to 600 ft). There are eight arrays with an 1828 m (6,000 ft) separation. The underwater track is 75 kHz phase-shift keyed (PSK) and is accurate to ± 0.9 m (3 ft) relative, ± 3.1 m (10 ft) absolute.

OBJECTIVES

This study was undertaken in direct response to new mandates in the Sustainable Fisheries Act of 1996 that require assessments of all activities with potential adverse impact on essential fish habitat, specifically those related to fishing gear. In particular, these gear trials were conducted to address the need for accurate information on trawl location during scientific fishing operations. The ability to resample specific areas is essential to experimental work planned for the Bering Sea, as part of AFSC trawling impact studies that began in 1996 (TRAWLEX).

The primary objective of this cruise was to compare the performance of three acoustic systems for real-time positioning of a bottom trawl net. Accuracy of each system will be quantified and compared by trawling within the inherently more accurate Dabob Range.

Additional objectives related to performance, implementation and cost of the ultra-short base line (USBL) systems were as follows:

- 1) evaluate the acoustic performance of each USBL system in terms of numbers of interrogations, returns and outliers (details in Data Analysis section below);
- 2) compare ease of installation of deck electronics, transducer and transponder, including power requirements, size and weight of equipment and (direct) interfacing to gyro, GPS and logging equipment;
- 3) compare the user friendliness and general utility of each system's software, to include an assessment of real time indicators of incoming data quality, the overall utility of graphical/digital displays available to the operator, internal data logging options, and the requirements for additional processing to produce real world coordinates from the raw data;
- 4) compare calibration procedures to compensate for head alignment errors due to installation and instrumental tilt errors;
- 5) identify requirements for additional hardware and determine whether third party software is required to effectively operate each USBL system and to display net position in real time so that it can be fished along a predetermined path;
- 6) determine if support personnel are required to install, calibrate and/or operate each USBL system and/or to process the raw data; and
- 7) evaluate the suitability and performance of the removable over-the-side hydrophone pole designed for this study.

VESSEL AND GEAR

Gear trials were conducted aboard the 37.8 m (124 ft) chartered commercial fishing vessel FV *Vesteraalen*. The *Vesteraalen* has a draft of 5.5 m, is powered by a 1725 hp main engine, and is

fitted with a propeller nozzle.

The bottom trawl used was an 83-112 eastern (Fig. 1). The 83-112 eastern trawl has been the standard sampling net used during annual AFSC eastern Bering Sea surveys since 1982. This net had a 25.3 m (83 ft) headrope and a 34.1 m (112 ft) footrope. In some cases, the net was equipped with a tickler chain, hula skirt, and a 3.81 cm (1.5 in) liner covering both wings as well as the entire bottom body, intermediate and codend. There was a 30 mesh overlap with a standard 3.18 cm (1.25 in) codend liner extending 65 meshes up from the terminus of the codend. These modifications are standard for AFSC trawling impacts studies in the eastern Bering Sea.

The 83-112 eastern trawl was towed behind 1,000 kg, 1.8 x 2.7 m, steel V-doors and 54.9 m (180.1 ft) paired dandylines. Each lower dandyline had a 0.61 m chain extension connected to the lower wing edge to improve bottom tending characteristics.

In keeping with standard AFSC sampling protocols, instruments that support area-swept and catch-per-unit-effort (CPUE) calculations were attached to the trawl. A (Scanmar®)¹ net mensuration system was utilized to monitor sampling net configuration and performance. The height sensor was attached to the center of the headrope and operated at either 41.417 (C-2) or 41.690 (C-5) kHz. Master and slave spread sensors were attached to the port and starboard wingtips of the trawl (respectively) and operated at either 42.631 (C-2) or 42.024 (C-5) kHz. On- and off-bottom times for the net were determined with an opti-mechanical bottom contact sensor attached to the footrope. Also, seawater temperature profiles were collected using a micro-bathythermograph attached to the headrope of the net.

Three ultra-short baseline (USBL) acoustic positioning systems were evaluated during the gear trials: 1) ATS II, manufactured by Nautronix, Inc., 2) ITI Wireless Trawl Positioning and Monitoring System, manufactured by Kongsberg Simrad, and 3) Trackpoint II Plus, manufactured by ORE International, Inc. These systems were installed and operated by technicians supplied by the manufacturers.

In order to utilize the Dabob Range for tracking, a pinger and battery pack were attached to the research trawl. These were mounted on a nylon board, housed in protective cages and cabled together. The pinger was synchronized to UTC time and operated at 75 kHz with output power of 193 dB (1µPa at 1 m). It was

¹Reference to trade names does not imply endorsement by the National Marine Fisheries Services, NOAA.

programmed to ping every 4 (optionally 2, 4, 8 or 16) sec. The fixed array, also synchronized to UTC time, recorded the time of arrival of each ping at each transducer. Since the epoch of each ping is known and the velocity of sound was observed, a range (or range difference) from each transducer to the pinger could be determined. These lines of position (LOP) were combined in a least squares adjustment to determine the coordinates of the pinger (trawl). Every hour upon recovery of the trawl, the pinger's clock was re-synchronized with a portable satellite receiver to correct for drift ($\sim 210 \mu\text{sec} \cdot \text{h}^{-1}$). Range tracking data were logged ashore at the nearby control center at Zelatched Point.

Sound velocities were determined with CTD casts made from a Navy support vessel, generally once each day. The CTD data were transferred to the *Vesteraalen*, processed and made available to the USBL operators before testing began.

A GPS receiver and a radio receiving USCG beacon transmissions on board the vessel provided differentially corrected positions in NMEA format. Vessel heading was obtained from a Sperry MK-37 gyro and a Lehmkuhl LR-22 or LR-40 repeater. During mobilization, a gyro survey was performed at K/B Docks by comparing the ship's centerline azimuth to the observed gyro azimuth. The azimuth of the ship was determined by measurements to the pier. The azimuth of the pier was obtained from the Navy (152° true). Position and heading of the vessel were fed to the USBL consoles and into the Navy's PC Range Graphics (PCRG) computer on the bridge. The PCRG computer graphically displayed the vessel and trawl positions with reference to a predetermined trackline. (Trawl position was transmitted to the *Vesteraalen* via an RF link with the range control center.) This display was used by the helmsman to steer the trawl along the desired trackline and provided other vessel navigation information, such as speed and heading.

The USBL transducers were mounted at the end of an over-the-side hydrophone pole (Fig. 2). The pole was a hybrid of several designs that had been used successfully in other applications and was collectively approved for the gear trials by all parties. The pole was comprised of four major components.

- 1) A downpipe of 15 cm diameter schedule 80 pipe extended from 3.25 m above the waterline to the keel of the vessel and was positioned outboard 0.46 m. At its upper end, the downpipe was bolted to the starboard bulwarks, just aft of the wheelhouse and forward of midships, at two flanges separated by 1.8 m. An upper 10 cm tension flange and a lower 15 cm pivot index flange were backed with 1.25 cm doubler plates for strength. The pivot flange allowed the pole assembly

and attached transducer to pivot out of the water when transiting at speeds above ~5 kts.

- 2) Attached to the end of the downpipe was an interchangeable 1.6 m adapter section of 10 cm schedule 80 pipe with pre-drilled bolt patterns to accommodate the different USBL transducers.
- 3) Located just below the waterline and attached to the vessel was a braced saddle on which the downpipe rested when fully deployed for tracking (*i.e.*, oriented vertically).
- 4) In order to reduce drag on the pole when deployed vertically for tracking, UHMW fairings (30.5 W x 99.1 L x 0.32 cm T) were positioned along the length of the downpipe. These were separated by 21.9 cm diameter donut spacers made of the same stock. Additionally, pad eyes were placed near the two ends of the main downpipe to enable attachment of fore and aft stays, if desired for stability.

ITINERARY

The *Vesteraalen* began the study at K/B Docks in Bangor, WA on 18 May and ended the study at K/B Docks in Bangor, WA on 29 May.

METHODS

Test procedure

Before commencing a test trawl, the range pinger was synchronized with UTC using a GPS TrueTime® and the GPS receiver synchronized the logging computers using NMEA sentence ZDA. This was to minimize latency effects that would confound USBL and SBL track comparisons. The hydrophone pole was pivoted from its out-of-the-water running attitude, positioned in the saddle and then bolted in place. The range pinger and battery pack were attached to the center of the trawl headrope. The USBL beacons were sewn into a mesh pocket(s) at the top of the net or directly aft of the Navy beacon, in either case they were at least 2 m from the Navy unit. The USBL beacons were secured to the headrope with a safety line and were turned on. Scanmar® sensors, the bottom contact sensor, and the micro-bathymograph were also attached to the trawl. The trawl was then deployed as far as the doors. After confirming that the Navy's tracking system and the USBL system were functioning, the vessel finished setting the gear and proceeded down the specified course at normal trawl speed (~3 knots). Tow wire length was consistently 273 m (150 fm) thus giving a depression angle from the horizontal of approximately

13° in 60 m of water. The USBL and Navy systems each logged data while trawling. At the end of each test, the trawl was retrieved only as far as the headrope to enable re-synchronization of the range pinger (if necessary). It was then re-deployed after a long, slow turn made to bring the vessel back to the original starting point. Since these gear trials were intended to demonstrate best possible performance of each USBL system, technicians were free to modify the deployment (e.g., reposition beacons) at will. The only requirement was completion of at least eight successful test trawls during the day of mobilization and two days of range time allocated for testing each USBL system.

Data collection

The requirement was to provide the position of the vessel and trawl while trawling. In order to compare trawl position from the USBL and NUWC systems, the time of each fix was required. Logged data were provided as comma-delimited PC-files where each line in a file constituted a record and was terminated by a line feed. The data in each record were as close as possible to the same epoch. For vessel position, each record included: vessel name, date and time of vessel fix, latitude of vessel, longitude of vessel and vessel heading. For trawl position, each record included: beacon code, date and time of beacon data, latitude of beacon, longitude of beacon, beacon depth, beacon range (raw USBL data), horizontal angle to beacon (raw USBL data) and vertical angle to beacon (raw USBL data). This record was repeated if multiple beacons were tracked. Either the range and angles were logged or X, Y and Z, at the discretion of the USBL operators.

Data analysis

Trawl positions obtained with USBL systems will be compared with those from the inherently more accurate (*i.e.*, fixed SBL) Dabob Range. Since the two systems determine locations at different times, individual fixes will not be compared. Instead time stamps will be used to interpolate USBL positions that match the time of a Dabob Range fix. Using the published USBL observational errors and the estimated errors from the GPS antenna to the USBL hydrophone, a variance will be produced for the USBL data. The Navy's estimate of 1.52 m (5 ft) for the accuracy of their system will be added to an estimate of the error due to a time difference between the Navy's system and the USBL logging clock. Only one variance will be computed for all the elements in a set. Thus there will be two sets of data with a statistical variance for each element in the sets. The nominal clock error will be calculated as follows:

$$F_t =)t V$$

where F_t is the approximate error due to clock difference, V is

the ship velocity and Δt is the estimated clock difference. Then an "assessment of parameters" statistical test comparing two independent determinations of the same point will be made. The mean and standard deviation of the difference in distance for each Navy point and corresponding USBL point will also be computed. In performing these comparisons, the data sets will be screened for outliers. A USBL observation will be deemed an outlier if its horizontal distance is greater than $2F$ from the average path of the trawl. The average path of a trawl will be determined from the other USBL observations and the measured perpendicular distance. The quantity F will be estimated by propagating the published USBL observational errors from the hydrophone to the average trawl location using the covariance law, then F will be calculated as the root mean square of F_x and F_y where x and y are the two axes of the vessel. Only one value will be determined for each test trawl. Other quantities will be calculated to evaluate the acoustic performance of the USBL systems, namely: (1) the ratio of returns to interrogations, (2) the ratio of outliers to returns, and (3) the ratio of returns less outliers to interrogations.

Graphical summaries of trawl positioning will also be produced. Plots will be made of each USBL track overlaid on the Navy track using the WGS84 (GPS) datum.

RESULTS

Field operations are summarized as follows:

Date	Major Activities
5/18/98	Clear Navy security; mobilize F/V <i>Vesteraalen</i> and ATS II at K/B Docks.
5/19/98	Nautronix ATS II testing on Dabob Range.
5/20/98	Nautronix ATS II testing on Dabob Range.
5/21/98	Demobilize Nautronix ATS II and mobilize Simrad ITI at K/B Docks.
5/22/98	Simrad ITI testing on Dabob Range; demobilize Simrad ITI at K/B Docks.
5/23/98	Trawl repair at K/B Docks.
5/24/98	Trawl repair at K/B Docks.
5/25/98	Trawl repair at K/B Docks.
5/26/98	Mobilize ORE Trackpoint II Plus at K/B Docks.

5/27/98	ORE Trackpoint II Plus testing on Dabob Range.
5/28/98	ORE Trackpoint II Plus testing on Dabob Range; demobilize at K/B Docks.
5/29/98	Demobilize <i>F/V Vesteraalen</i> .

Nautronix ATS II test

AFSC, Nautronix and Vesteraalen personnel cleared Navy security the morning of 18 May and proceeded to K/B Docks for mobilization. Trawl gear was mounted on the two stern net reels, while range tracking hardware and software were installed on the bridge of the vessel. Nautronix technicians installed the ATS II system, including a vertical reference unit (VRU) and *WinFrog*® software for data logging, and performed a static calibration to determine appropriate offsets. The ship's gyro was calibrated.

After a safety orientation, the vessel departed K/B Docks at 0535 on 19 May and proceeded to the Dabob Range. A preliminary survey using the vessel's fathometer and chart recorder was performed to evaluate the feasibility of trawling in the two pre-selected test areas (Fig. 3). The primary test site, with centerline defined by (lat. 47°47'00.4"N, long. 122°49'21.8"W) and (lat. 47°46'25.5"N, long. 122°50'15.8"W), was rejected because of a gully that bisected the trawl path. The alternative site, with centerline defined by (lat. 47°44'57.2"N, long. 122°50'35.7"W) and (lat. 47°44'23.1"N, long. 122°50'53.2"W), was selected despite evidence of a hard bottom hazard, which was subsequently confirmed to include large boulders. Other areas were not considered because of specific depth requirements for AFSC research in the Bering Sea, the need for line-of-sight communication between the trawl-mounted pinger and range hydrophones located at the center of the U-shaped Dabob basin, and in consideration of other range activities and infrastructure (e.g., submarine operations, practice mine fields, array fixtures and associated cabling). Additional surveying and exploratory fishing at the alternative site identified a suitable path for 10-15 min tows in ~60 m of water. CTD data collected by the Navy indicated a nearly vertical temperature profile. Preliminary tows confirmed proper operation of net mensuration and range tracking equipment and ruled out acoustic interference. Before returning to K/B Docks at ~1900, one test tow was performed with a single beacon (code 187) positioned 4.6 m (15 ft) behind the range pinger. The beacon tracked well once submerged below 40 m depth. Trawl gear was repeatedly damaged by boulders and other debris and frequently fished off the centerline of the vessel due to currents. Eight additional test tows were performed on 20 May, beginning at 1300 and continuing until after 2300. (The testing schedule was shifted so as to avoid conflict with a recreational shrimp pot fishery in Hood Canal.) The USBL beacon

was repositioned closer to top-center of the headrope at 2.6 m behind the range pinger. Once again, trawl gear was repeatedly damaged by boulders and other debris and was frequently fishing off the centerline of the vessel due to currents. All tows were taken in a generally southward direction. Although erratic gyro behavior occurred (Lehmkuh LR-22 repeater), the Nautronix technicians were not concerned because any errors could be removed during post-processing of the data. Overall, they were generally pleased with the performance of the ATS II system and the conduct of the test. Nautronix gear was demobilized at K/B Docks on 21 May and technicians departed.

Kongsberg Simrad ITI test

Simrad personnel cleared Navy security the morning of 21 May and proceeded to K/B Docks for mobilization. Simrad technicians installed the ITI system including a 27-33 kHz triple beam transducer (40° vertical coverage for a single beam, and 100° aggregate horizontal coverage), *ECC Globe*® electronic chart navigation software, as well as depth, temperature and catch sensors. Calibration of the ITI system was not necessary. Navy ETs replaced the older Lehmkuhl LR-22 gyro with a newer model LR-40.

After a safety orientation, the vessel departed K/B Docks at 0500 on 21 May and proceeded to the Dabob Range. CTD data collected by the Navy indicated a nearly vertical temperature profile. A preliminary tow was conducted with ITI sensors only, to confirm proper operation. Twelve additional test tows were conducted before returning to K/B Docks. All tows were taken in a generally southward direction. As before, trawl gear was repeatedly damaged by boulders and other debris and was frequently fishing off the centerline of the vessel due to currents. Two serious problems were encountered with the ITI system which will compromise positioning data and, ultimately, a comparison with Navy tracking data. The ITI depth sensor malfunctioned and did not provide reliable data. Depth data are an essential input for trawl positioning with the ITI system, since the transducer itself does not directly measure the depression angle to the net. A catch sensor was substituted to generate range data (*i.e.*, target distance only) and a constant depth value was input manually. This approach, however, does not account for variable geometry related to depth and thus introduces (net) positioning error. Also, the ITI did not log time-stamped trawl positions. By design, the ITI interrogates a sensor every 4 sec to determine net position, but does not output time with the determined position. Attempts in the field to resolve the problem, including installation of a second DGPS receiver and reformatting of data with *WinFrog*®, were unsuccessful. The vessel returned to K/B Docks at ~2100, the ITI system was removed and technicians departed. Overall, Simrad

technicians felt that the ITI system performed well and that good trawl positioning was accomplished.

ORE Trackpoint II Plus test

AFSC and ORE personnel cleared Navy security the morning of 26 May and proceeded to K/B Docks for mobilization. ORE technicians installed the Trackpoint II Plus system, including a VRU mounted on the main deck at the centerline of the vessel just aft of the wheelhouse, a flux gate compass mounted on top of the wheelhouse, and *HyPack*® software for data logging. A dynamic calibration to determine offsets was performed that evening by circling a beacon trailed behind a drifting skiff. At this time, audible drumming of the hydrophone pole was noted while underway at trawling speed. Two modifications resolved the problem (see below).

After a safety orientation, the vessel departed K/B Docks at 1300 on 27 May and proceeded to the Dabob Range. Departure time was delayed so as to avoid conflict with a recreational shrimp pot fishery in Hood Canal. Two beacons (27 and 26 kHz transmit; 19 and 21 kHz receive) were placed at 4 m on either side of the center of the headrope. Ten test tows were completed before returning to K/B Docks at midnight. The *Vesteraalen* departed K/B Docks at 0700 on 28 May and proceeded to the Dabob Range. CTD data collected by the Navy indicated a stratified water column. Fours tows were completed before returning to K/B Docks at ~1300 at which time the Trackpoint system was removed and technicians departed. Damage to trawl gear was somewhat less frequent than before, however, the trawl continued to fish off the centerline of the vessel due to currents. All tows were taken in a generally southward direction. Overall, the ORE technicians were satisfied with the conduct of the test and the performance of the Trackpoint system. Initially there was some difficulty interfacing the LR-40 gyro repeater and the *HyPack*® software, apparently related to baud rate limitations in a software driver, and the flux gate compass was used. (ORE technicians were expecting the older LR-22 repeater.) This problem was resolved early the first day and did not affect the final logged data.

Hydrophone pole performance

Because of the sensitivity of USBL tracking to performance of the hydrophone pole, special mention is warranted. The hydrophone pole developed for these gear trials performed very well, such that USBL field technicians not involved in the design process commented that it was probably the best overall design they had used. However, careful scrutiny suggests a few refinements to address minor shortcomings. Fairings had a tendency to distort and slide along the downpipe, suggesting that bolts holding the folded panels should be carefully positioned and that larger (outside) diameter spacers were needed. One USBL technician

suggested that the folded fairing panels should be longer and that standard sizing guidelines exist. Also, flexing of the vessel's bulwarks where the (lower) pivot flange was secured occurred after several days use. This was first noticed as an audible drumming sound when the vessel was underway and, on closer inspection, flexing of the doubler plate over the pivot flange cutout (27.9 cm diameter) was observed. The tolerance between the downpipe and the saddle was too large allowing the downpipe to knock against the saddle. The downpipe was wrapped in 6 mm rubber sheet at the point of contact with the saddle and a guy wire (7.9 mm diameter) was attached to the lower pad eye of the pole and secured near the ship's bow. This resolved the problem. Alternatively, the doubler plate covering the pivot flange cutout could be gusseted to reinforce the bulwarks and prevent flexing.

PERSONNEL

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83/112 EASTERN

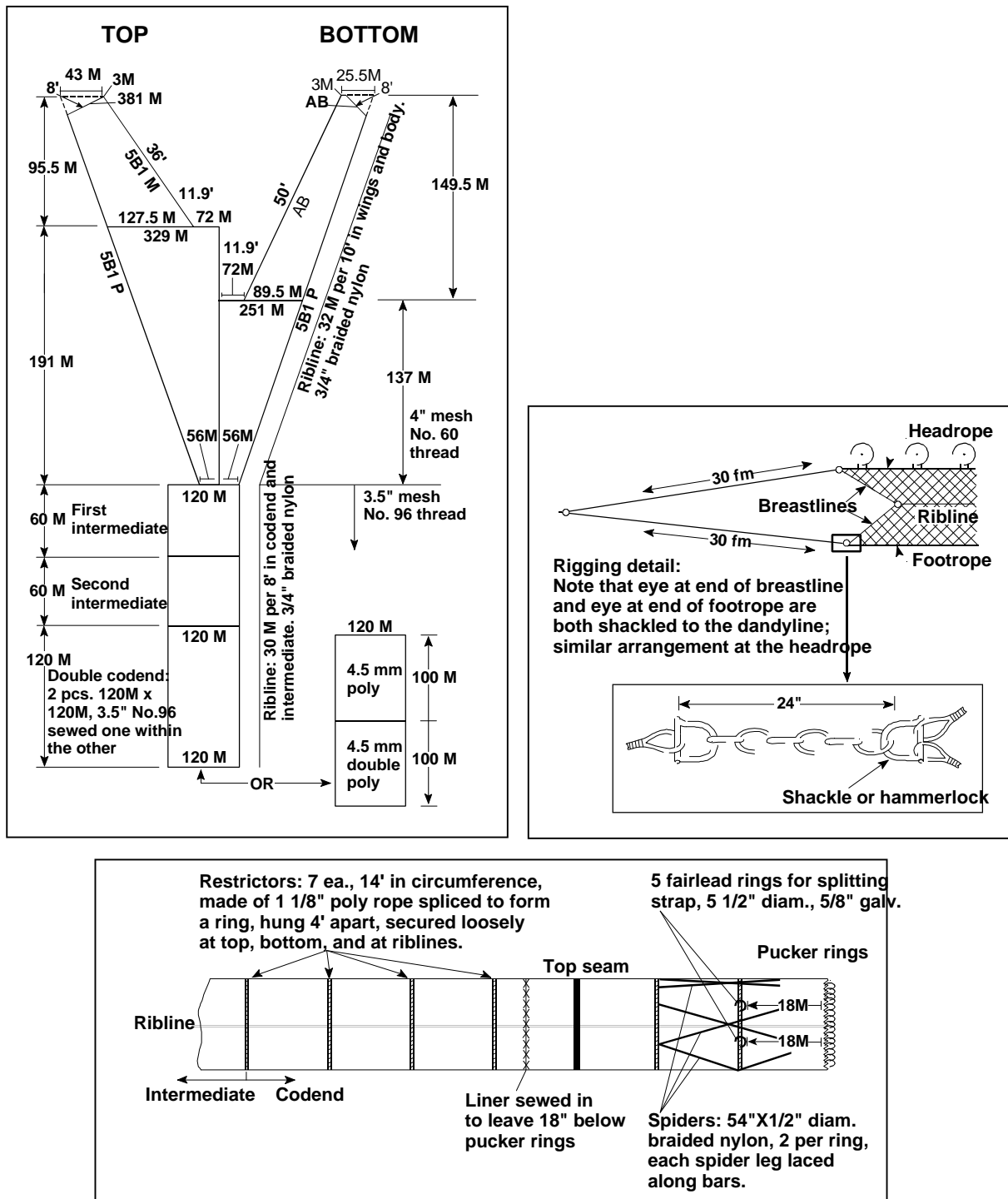


Figure 1. Diagram of the 83-112 bottom trawl used in the 1998 trawl positioning gear trials .

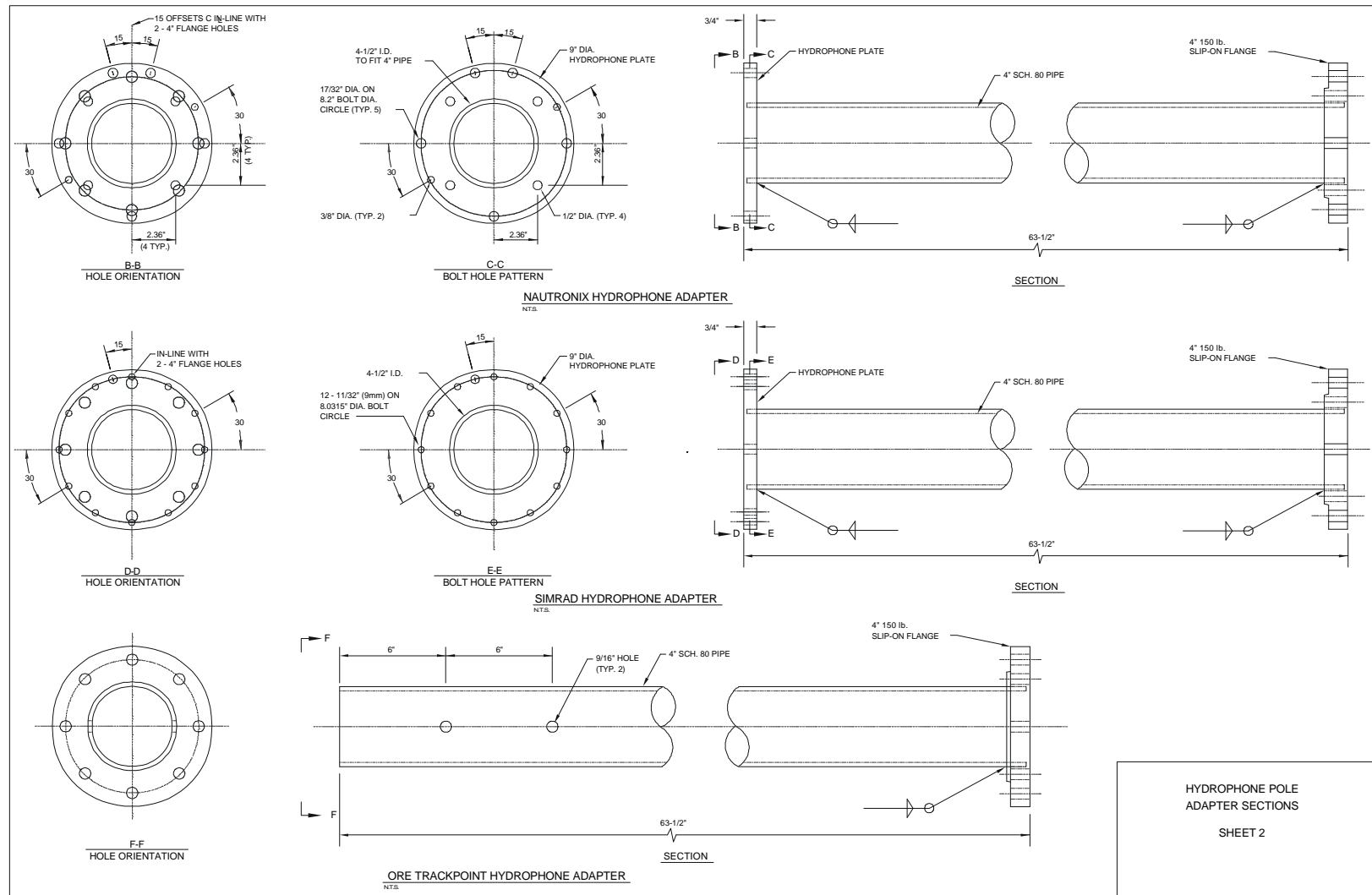


Figure 2. Hydrophone pole used in the 1998 trawl positioning gear trials.

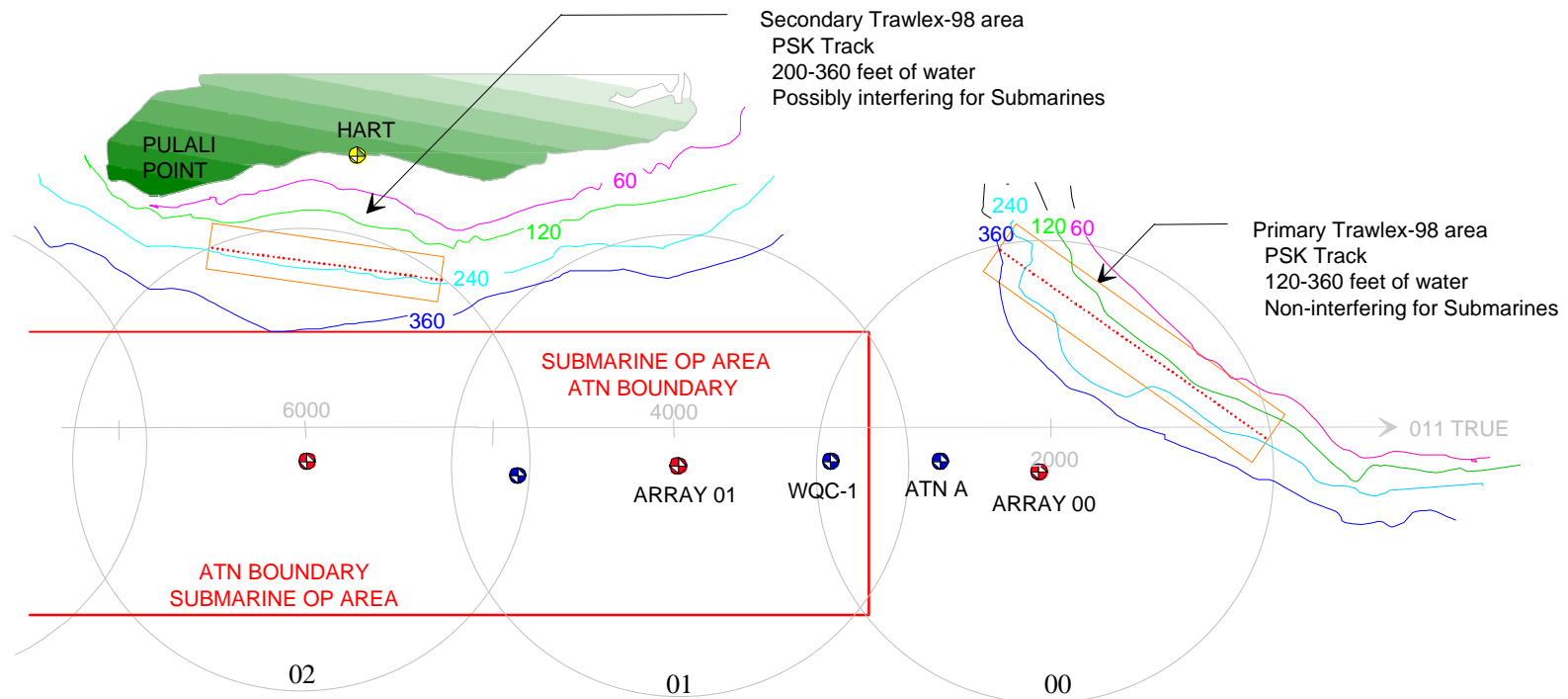


Figure 3. NUWC Dabob Range test areas for 1998 trawl positioning gear trials (NUWC run plan #3173).